PROSPECTING IN NEW BRUNSWICK (SESSION II)

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(SESSION II)

Mineral Resources Division
Department of Natural Resources
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NOTES

on

PROSPECTING IN NEW BRUNSWICK

by

W.E. Hale

SESSION TWO

ROCKS AND ORES

January, 1981

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PROSPECTING IN NEW BRUNSWICK
W.E. Hale

SESSION TWO
ROCKS AND ORES

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NOTES TO ACCOMPANY
PROSPECTING IN NEW BRUNSWICK
W.E. Hale

Session Two (of 6)

ROCKS AND ORES*

2.1.0 Rocks

2.1.1 Rocks and Ores

All ores (metallic, non-metallic), as well as deposits of mineral fuels and structural materials, are themselves rocks or occur in various rock types. Many attempts have been made to classify specific ores or ore minerals with specific rocks but a complete and strict classification of this type is not yet possible. Some 'controls' by various types of rocks on the distribution of some ore minerals can be demonstrated, e.g. the tendency for many copper deposits to be associated with dioritic rocks has been known for over 50 years. Knowledge of rock-ore associations is useful for the prospector as a guide to what he may expect in the field but he should not be completely restricted by them in his search for new occurrences.

*The notes for this session merely provide some background material. The studies of rocks and ores are the major concerns of economic geologists and prospectors and in this short program only a brief introduction can be attempted. 'Scanning' the references for this course will indicate the emphasis applied to the study of these materials. The trainee should use the two required references and practise with the collections to extend his/her knowledge of this essential part of the prospector's education.

An ore has been defined as a mineral or association of minerals (rock) from which one or more elements or compounds can be profitably extracted at a given place in a given time. As noted already, many non-mineralogical factors (e.g. access, demand, supply, price, etc.) must be taken into account in the identification of an ore but it is true that they are all minerals or rocks.

2.1.2 The Rock Cycle

Rocks are solids consisting of one or more minerals. They make up the earth's solid crust down to a depth at which high temperatures result in melting. The thickness of the crust varies in different parts of the earth but averages about 35 km under the continents. (It averages about 8 km under the deeper oceans). Although rocks are by definition solid and the crust is made up primarily of solid rocks (mostly igneous), there are fluids (gases and liquids, such as water, carbon dioxide, hydrochloric acid, sulphuric acid, sulphur dioxide, etc.) in the crust and in unconsolidated materials (such as sand, clay, gravel, oceanic oozes, etc.) on the crust. We tend to think of the surface on which we live, as have our ancestors before us, as being stable for all time. Geologically speaking, however, and particularly in terms of geological time, the earth's crust and the fluids enveloping it are in a state of constant change. Rocks are being slowly created and destroyed 'before our eyes' in a cycle of processes illustrated in Fig. 1. This figure shows, in simplified form, the various and complex processes that take place in and on the crust and that form and reform rocks.

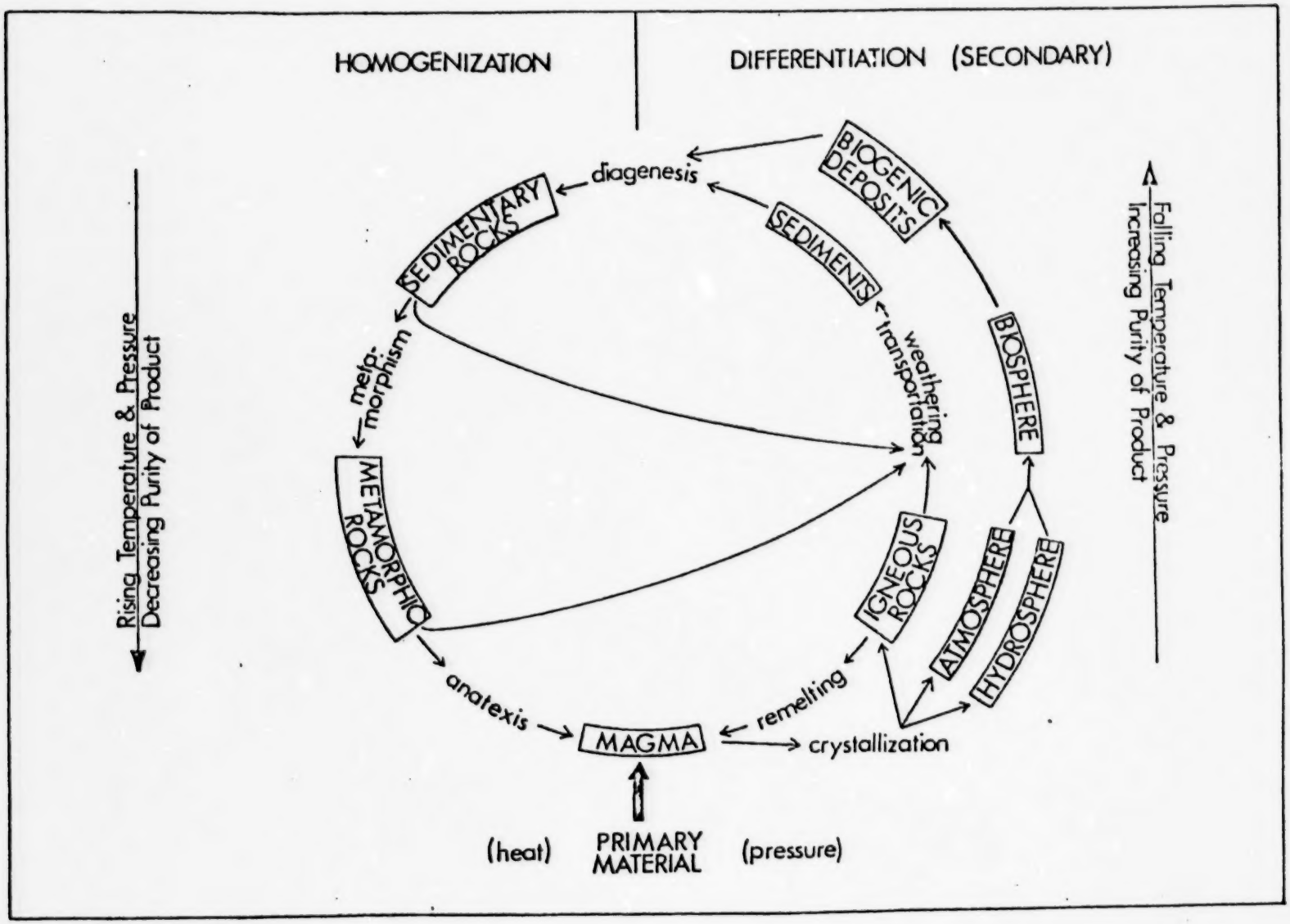

Figure 1. Rock Cycle (After Mason, 1958)

2.1.3 Identifying Rocks According To Their Origin

When the geologist refers in his reports or on his maps to the three major types of rocks: igneous, sedimentary and metamorphic, he is actually referring to the origin of the rocks. In the field, it may be difficult or impossible to determine the origin of a rock and thereby give it a name. However, understanding, even in an elementary way, how rocks form, gives the prospector an idea of what to look for in tracing a 'favourable formation' or 'reading' a geological map.

A word of caution for the prospector applies to the naming of rocks. Many techniques: chemical, optical, x-ray are used in modern identification of rocks. The prospector usually does not have access to these refined methods and therefore, he should not expect to give names to rocks with the same authority or confidence that the government geologist can do on the basis of laboratory study of 'his' rocks. This is particularly true of fine-grained rocks in which individual minerals and their proportions can not be determined by the naked eye or with a hand lens.

2.1.4 Rock Outcrops

Later in this program we shall describe the manner in which geological maps are made and used. It may be worthwhile, however, to explain here that when we speak of rocks, particularly in the field, we are referring to outcrops or exposures of the crust. The natural surface on which we walk in the field (in the bush, in the woods) consists of many materials other than rock. In N.B. we have soil formed from the weathering

of former rocks, we have till, gravels, sands, clays previously transported and spread over the surface by rivers, lakes, glaciers and we have decaying vegetable matter formed from trees and other plants. None of these materials is rock. What we term rock is the solid, natural material that we see in cuts a ong highways and rivers where man or water has cut through the soil and other loose, unconsolidated material to the crust. Away from highways and rivers these crustal materials "pop through" the unconsolidated material where it is thin or has been moved by nature or man. Geological maps commonly show rock types as continuous areas when in fact these areas (coloured in solidly or shown in a continuous pattern) are interpreted from a few scattered outcrops that may represent less than 5% of the actual area. For the prospector the outcrops of rock are the important thing and maps that show these and exhibit a different pattern or colour for the unconsolidated material and non-rock are the most useful.

2.1.5 Diagnostic Characteristics of Rocks

To confidently name a rock, understand its origin and history and thus its potential as a source or host for ore, you would wish to know:

composition - { chemical (has to be determined in a lab)
mineralogical (proportions of individual minerals)

texture - (the shape and size of individual minerals and their spatial arrangement with one another)

structure - (geometric or other spatial features not confined to individual grains or their intergrowths, eg. bedding)

mode of occurrence - (the form or shape of the rock type as a whole eg., dyke, beds, etc.)

distribution - (where the rock occurs, whether repeated, dislocated, etc.)

age - relative (to other rocks in the area or region)
absolute (in actual years as determined by radioactive methods)

associations - (with other rock types)

correlations - (equivalence with the same or similar rocks outside the area)

alteration - (all the changes including metamorphism through which the rock may have gone since its origin)

Working with your collections for this program, you will do well to know the mineralogical composition, texture and in some cases, structure. In the field you can probably determine the structure, mode of occurrence and perhaps obtain partial information on some of the other characteristics. These limitations are noted here to forewarn you that identification of all rocks is not a simple matter and that you should not be discouraged if, after examining a rock and noting the characteristics you can see with the hand lens, you are unable to confidently assign it a name. Some rocks are easy to identify e.g., limestone (bedded, soft to the knife and fizzes with HCl),

others, such as a welded rhyolite tuff, will require generally more sophisticated techniques than you have available in the field.

2.1.6 Rock Descriptions and Classification

Your texts (pp. 30-38 inclus.) and lab manuals (CH. 3, 4, 5) provide useful advice and guidance in the study of rocks. The lab manual in particular will serve as a practical reference in the recognition of diagnostic properties and naming of rocks. (Practice, with specimens indoors but more critically in the field, will allow the prospector to make some allowances for colours in the illustrations).

(After reading the text (Lang, 1970) and the sections of the lab manual dealing with the main rock types, attempt to answer the lab manual problems (igneous, p. 34; sedimentary, p. 50 and metamorphic, p. 57)).

2.2.0 Ores

2.2.1 General Comments

Some information concerning ores is presented here although it is acknowledged that the trainees' preparation at this stage is limited. Additional reading from the references will be necessary. Information to be provided in later sessions of this program will also contribute to an understanding of ores. This understanding of ore deposits and hence the ability to search intelligently for them, is based primarily on two subdivisions of geological science: mineralogy-petrology (the study of minerals and rocks) and structural geology (the study of

the spatial distribution or size, shape, form of, geological materials). Appendix III, p. 276 of your texts (Lang, 1970) lists the abundances of chemical elements in "average igneous rocks" which geologists believe represent approximately the average composition of the earth's crust.

2.2.2 Abundances of Economically Important Elements

From the tabulation of the crustal abundances of the elements, we can select those that are economically important (Table 2-1).

TABLE 2-1. Crustal abundance of economically important elements*

Name	Chemical Symb.	Atomic No.	Crustal abundance (% by weight)
Aluminum	Al	13	8.00
Iron	Fe	26	5.8
Magnesium	Mg	12	2.77
Potassium	K	19	1.68
Titanium	Ti	22	0.86
Hydrogen	H	1	0.14
Phosphorus	P	15	0.101
Manganese	Mn	25	0.100
Fluorine	F	9	0.0460
Sulfur	S	16	0.030
Chlorine	Cl	17	0.019
Vanadium	V	23	0.017
Chromium	Cr	24	0.0096
Zinc	Zn	30	0.0082
Nickel	Ni	28	0.0072
Copper	Cu	29	0.0058
Cobalt	Co	27	0.0028
Lead	Pb	82	0.00010
Boron	B	5	0.0007
Beryllium	Be	4	0.00020
Arsenic	As	33	0.00020
Tin	Sn	50	0.00015
Molybdenum	Mb	42	0.00012
Uranium	U	92	0.00016
Tungsten	W	74	0.00010
Silver	Ag	47	0.000008
Mercury	Hg	80	0.000002
Platinum	Pt	78	0.0000005
Gold	Au	79	0.0000002

*(Source: Press and Siever, Earth, 2nd ed., 1974. W.H. Freeman and Co., San Francisco).

It is important to realize that 'abundance' does not mean availability. For example, gold is familiar to all of us and the metal gold we've seen may have been a nugget essentially as it occurred in nature. On the other hand, no one has seen the metal aluminum in the natural setting since it invariably occurs combined with other elements such as oxygen, silicon, etc. The combination of these and other elements with aluminum results in compounds such as bauxite, feldspars, clay minerals, etc. that have properties very unlike those of the metal aluminum. To get the metal aluminum, with which we are familiar, man must extract it from the natural compounds in which it occurs. We are, therefore, much more familiar with gold, the least abundant of the economically important elements, in its natural state, than we are with aluminum, the most abundant of these elements in its natural state. This observation is intended to demonstrate two important facts:

1) The form in which we use an element of the earth's crust is not necessarily the form in which it occurs in that crust and,

2) In order to find, mine and process the elements we require, it is necessary to know something about how and where they occur in nature, i.e. the minerals, rocks and ores that contain them.

2.2.3 Ore Minerals

Most of the elements required for use in our modern society are obtained from the minerals listed in Table 2-2, p. 10. With the exception of the native elements (gold, silver and copper), the ore minerals represent compounds from which the useful element(s) must be extracted. This extraction is called,

TABLE 2-2. List of the Common Ore Minerals*

Metal	Ore Mineral	Composition	Percent Metal	Primary	Supergene
Gold	Native gold	Au	100	X	X
	Calaverite	$AuTe_2$	39	X	
	Sylvanite	$(Au,Ag)Te_2$	—	X	
Silver	Native silver	Ag	100	X	X
	Argentite	Ag_2S	87	X	X
	Cerargyrite	AgCl	75		X
Iron	Magnetite	$FeO \cdot Fe_2O_3$	72	X	
	Hematite	Fe_2O_3	70	X	X
	"Limonite"	$Fe_2O_3 \cdot H_2O$	60		X
	Siderite	$FeCO_3$	48	X	X
Copper	Native copper	Cu	100	X	X
	Bornite	Cu_5FeS_4	63	X	X
	Brochantite	$CuSO_4 \cdot 3Cu(OH)_2$	62		X
	"Chalcocite"	Cu_2S	80	X	X
	Chalcopyrite	$CuFeS_2$	34	X	X
	Covellite	CuS	66	X	X
	Cuprite	Cu_2O	89		X
	Digenite	Cu_9S_5	78	X	X
	Enargite	$3Cu_2S \cdot As_2S_5$	48	X	
	Malachite	$CuCO_3 \cdot Cu(OH)_2$	57		X
	Azurite	$2CuCO_3 \cdot Cu(OH)_2$	55		X
	Chrysocolla	$CuSiO_3 \cdot 2H_2O$	36		X
Lead	Galena	PbS	86	X	
	Cerussite	$PbCO_3$	77		X
	Anglesite	$PbSO_4$	68		X
Zinc	Sphalerite	ZnS	67	X	
	Smithsonite	$ZnCO_3$	52		X
	Hemimorphite	H_2ZnSiO_5	54		X
	Zincite	ZnO	80	X	
Tin	Cassiterite	SnO_2	78	X	?
	Stannite	$Cu_2S \cdot FeS \cdot SnS_2$	27	X	?
Nickel	Pentlandite	(Fe,Ni)S	22	X	
	Garnierite	$H_2(Ni,Mg)SiO_3 \cdot H_2O$	—		X
Chromium	Chromite	$FeO \cdot Cr_2O_3$	68	X	
Manganese	Pyrolusite	MnO_2	63	X	X
	Psilomelane	$Mn_2O_3 \cdot xH_2O$	45	X	X
	Braunite	$3Mn_2O_3 \cdot MnSiO_3$	69	?	X
	Manganite	$Mn_2O_3 \cdot H_2O$	62		X
Aluminum	Bauxite	$Al_2O_3 \cdot 2H_2O$	39		X
Antimony	Stibnite	Sb_2S_3	71	X	
Bismuth	Bismuthinite	Bi_2S_3	81	X	X
Cobalt	Smaltite	$CoAs_3$	28	X	
	Cobaltite	CoAsS	35	X	
Mercury	Cinnabar	HgS	86	X	
Molybdenum	Molybdenite	MoS_2	60	X	
	Wulfenite	$PbMoO_4$	39		X
Tungsten	Wolframite	$(Fe,Mn)WO_4$	76	X	
	Huebnerite	$MnWO_4$	76	X	
	Scheelite	$CaWO_4$	80	X	
Uranium	Uraninite	Combined UO_2	50-85	X	
	Pitchblend	and UO_3		X	
	Coffinite	$USiO_4$	75		X
	Carnotite	$K_2O \cdot 2U_2O_3 \cdot V_2O_5 \cdot nH_2O$	60 U_3O_8		X

*Source: Jensen and Bateman, 1979, Economic Mineral Deposits, 3rd ed., John Wiley, New York.

"mineral processing" and involves physical, chemical and thermal techniques for separating elements.

These ore minerals are the prospector's targets in the field. Few, if any, prospectors could identify all of these minerals but the qualified prospector should be able to recognize many of them and be aware of the possibilities for the association of the less common minerals with those that are more familiar and easily recognized.

The identification of ore minerals in a rock is a favourable indication but the percentage of metal (Table 2-2, p. 10) applies only to the pure mineral itself. When this ore mineral is scattered through a rock and the rock as a whole has to be mined and crushed to release the ore mineral, the % of metal in the rock to be mined is much less. An example may serve to illustrate this.

Chalcopyrite, the most common ore mineral of copper, contains 34% of the metal copper. If the mineral chalcopyrite is scattered through a diorite such that it makes up approximately 2% of the weight of that rock, then the rock to be mined contains: 35% of 2% of the rock, or 0.7%Cu. This would probably constitute an ore only if the diorite containing the chalcopyrite was extensive enough to sustain mining at a rate in excess of 1000 T/d. for about 20 years. Even with sufficient quantity of diorite (minimum 7,000,000 tons) proven, the actual recovery of copper would be less than that indicated since recovery is never complete and some of the copper would be lost in the processing.

Prospectors are notoriously optimistic and, if this were not so, many major ore bodies would not have been discovered.

However, the successful prospector will understand the difference between an ore mineral and an ore. The difficulty for the prospector commonly arises from the fact that it is rarely possible to see or measure the 7,000,000 tons referred to above. The prospector who does find 2% chalcopyrite in a diorite outcrop is likely to be able to see directly 10 or 20 tons of diorite at the surface. What happens to the diorite and the chalcopyrite it contains where it disappears under 'drift' or another rock, commonly has to remain a mystery until drills outline the body sufficiently to verify the 7,000,000 tons and the continuity of the 2% chalcopyrite within it.

2.2.4 Ore Formation: Anomalies

Table 2-3 may assist in the understanding of how unusual or abnormal an ore body is in the earth's crust.

TABLE 2-3*. Concentration factors of some economically important elements needed for profitable mining.

Element	Crustal Abundance (% by weight)	Concentration factor*
Aluminum	8.00	3-4
Iron	5.8	5-10
Copper	0.0058	80-100
Nickel	0.0072	150
Zinc	0.0082	300
Uranium	0.00016	1200
Lead	0.00010	2000
Gold	0.0000002	4000
Mercury	0.000002	100000

Sources: Data from B.J. Skinner, Earth Resources, Prentice-Hall, 1969; D.A. Brobst and W.P. Pratt, Mineral Resources of the U.S., U.S. Geological Survey, Prof. Paper 820, 1973.
*Concentration factor = abundance in deposit/crustal abundance.

*Source: as in Table 2-2.

The fact that a typical gold ore deposit is approximately 4000 times richer in this element than the earth's crust as a whole accounts for the rarity of these deposits. The saying "Gold is where you find it", can be applied to all ores, certainly in the literal sense. However, the modern prospector can improve on the suggestion implied in the saying namely, that discovery is simply a matter of luck, if you are in the right area. If the saying is taken to mean that new discoveries of gold are likely to be made in areas where gold mines are already known, then it has both statistical and geological validity since it is known now that ores of a certain type or element tend to occur together in certain areas of the earth's surface. These relatively small, areas, or 'provinces' or 'camps', in which some elements are abundant enough to be mined are obviously portions of the outer earth in which conditions have been different from the average where no mining is possible (due to the fact that the economically important elements are not concentrated above the average). These areas, in which elements are concentrated above the crustal average, are abnormal or anomalous. Whereas this generalization is obvious, the processes by which certain parts of the earth become preferentially enriched in valuable elements is not fully understood. It is sufficient to indicate to the beginning prospector that, "ore is where you find it", and that you will most likely find it where ore is already known since these are areas already proven to be other than average.

The departure from the average for the earth's outer shell may be expressed in ways other than, or additional to, the anomalous concentration of some elements. Physical, chemical,

structural, petrological differences from the normal often provide clues to good prospecting ground before ore is actually found. In the Bathurst-Newcastle Camp of northern N.B. electrical and magnetic irregularities in this part of the earth's crust were detected before ore was known.

As in other studies of nature, the prospector has to be aware of the normal geological processes and products in order to be able to recognize the abnormal with which ore may be associated.

Ore minerals obey the laws that govern all the various geological processes but their concentration into an ore deposit, that can be profitably mined, requires special conditions that are best recognized when the normal conditions are understood.

(More detailed and specific information on ore deposits is contained within the Additional References recommended for this program. In the context of ore minerals and deposits, References 4, 9 and 11 may be helpful).

2.2.5 Ore Associations

A comprehensive classification of ore associations with specific rock types, based on world-wide ore occurrences, will be found in Reference 9 (p. 22 and p. 108).

Further discussion of ore - rock associations will be found in the notes dealing with Surface Processes (Session Three) and Subsurface Processes (Session Four).

2.2.6 Exploration for Ores

Diligence and luck still play important roles in prospecting. Diligence in the careful coverage of ground for (ore) 'mineralization' that others have missed is still yielding 'finds' and will continue to do so. (High-grade sulphide mineralization in boulders had been known in the Bathurst area of N.B. for approximately 100 years before it was discovered in ore quantities in place. Furthermore, some of the Bathurst ore occurrences now known were within reach of grub hoes and surface trenches). Even in comparatively accessible areas, there is scope and potential for the prospector who checks new rock exposures made during road construction, stream erosion and other processes that bare 'new' rock. On the other hand, the modern prospector need not depend solely on diligence in ground coverage and luck. New information and improved techniques for mineral exploration now assist and guide the prospector in his 'coverage'. Your texts (Lang, 1970, Sections 8-13 incl.) and Reference 9 (Peters, 1978, Part Four) describe some of the techniques and services available to prospectors.

a. Geological Methods

The prospector operating in Canada and particularly N.B., has at his disposal geological information, primarily from the Department of Natural Resources, Mineral Resources Branch, that reduces the luck factor in his exploration. He requires a basic understanding of geology in order to intelligently use this service.

Examples of topographic maps, geological maps, reports and related information will be provided in Sessions Three and Four.

In general the prospector uses geological information to select areas of potential interest for his more detailed investigation. His concern is with ore minerals initially and from the occurrence of these, the prospects of ore itself. Where ore minerals have been encountered in the course of geological mapping, their location and a generally brief description are noted on the map itself or in the report accompanying the map. The prospector should understand, however, that geologists mapping and reporting on a particular area have as their objectives the identification of the rock types present and their relationship to one another in time and space. In order to meet these objectives, within the field season(s) available, the geologist seldom has the time required for careful prospecting. Indeed, he may not be qualified by temperament, interest and experience to carry out the specialized prospector's role. The prospector should therefore view geological maps and reports as helpful contributions in his planning and fieldwork. With further study, the prospector should be able to use the (inexpensive or free) government geological maps and reports to tell him what geological processes have gone on in an area, what products (minerals and rocks) have been produced by these processes and hence, what ore minerals might be associated with these materials. He may then choose to concentrate his search in those rocks (which he has learned to identify) in which specific ore minerals are known to occur preferentially.

b. Geophysical Methods

Some prospectors acquire and use their own geophysical instruments such as radiation counters, magnetometers and similar, simple, relatively inexpensive 'tools' in exploration. Geophysical exploration, however, is a specialized branch of prospecting that requires some knowledge and practice additional to that given in this program. The methods used are outlined in (Section 12, p. 135 of your texts and in Section 13, p. 363 of Reference 9).

Partly to assist prospectors, the federal and provincial governments have financed and are financing geophysical surveys, mostly from the air. These surveys, the data from which are plotted on aeromagnetic, aeroradiometric and other maps, provide additional useful information for the prospector.

In a general and very elementary sense geophysical maps illustrate the magnetic or radiometric or other physical characteristics of the earth's surface and upper crust within the area of the survey. Results of this kind generally do not identify directly ore bodies, oil fields, etc. What these surveys do provide is evidence of irregularities or anomalies in the respective physical characteristics relative to the 'average'. These anomalies may indicate uncommon or 'non-average' conditions with which ore may be associated.

With some guidance and experience, the prospector can further concentrate his search, not only in those areas in which he knows (from geological maps) that certain geological processes have taken place, but in anomalous portions of those same areas.

The magnetically anomalous rocks, with which the Brunswick No. 6 and 12 ore bodies are associated, were identified geologically by the late Dr. G.S. MacKenzie, U.N.B., and in an aeromagnetic survey carried out in that area in the early fifties. Ground confirmation of the airborne results and the application of other geophysical techniques indicated markedly anomalous conditions below the surface in parts of this survey area. Subsequent drilling revealed that massive Pb-Zn sulphides are associated with these geologically and geophysically anomalous conditions. This 'success story' provides an excellent example of the use of geological and geophysical methods in the search for ore minerals and ore. However, it must be pointed out that the airborne surveys referred to also indicated geophysically anomalous zones with which no massive sulphides are associated.

c. Geochemical Methods

Refined instruments and techniques for quantitatively detecting minute amounts of ore elements have been developed since the early 50's. When a 'buried' ore body, representing an abnormal concentration of ore minerals, is exposed over 100's, 1000's of years to circulating ground water and the dissolved 'agents' that it carries, some of the ore elements will be picked up by this water and carried to the surface where deposition may occur in soils and stream sediments or the ore elements may remain in the water of wells, springs or streams. Chemical analysis of these materials (soils, stream sediments, waters) may

indicate an area of the earth's surface in which the concentration of ore elements is above average and therefore anomalous. This is the essence of geochemical exploration. The methods of sampling are inexpensive and some methods of analysis can be carried out inexpensively in the field by a prospector. (Methods are described in your texts, Section 13, p. 168 and in Reference 9, p. 397).

As in the case of exploration geophysics, the provincial Dept. of Natural Resources in N.B. (and similar agencies in other jurisdictions) carries out geochemical surveys that provide the prospector with this type of data in the form of maps and reports. (Examples of these reports will be provided in Session Five).

d. Integrated Exploration

It should be obvious by now that the intelligent way to explore for ore deposits or those of the mineral fuels is by using all available geological, geophysical and geochemical survey results. This is, in fact, the approach adopted by exploration companies and experienced prospectors. In some areas, and for some other reasons, the exploration organization may conduct its own surveys but, even in such cases, the available data provided by government agencies is reviewed beforehand. For the individual prospector operating in New Brunswick, a wealth of information is available in published, inexpensive form and he/she should qualify him/herself to use this.

2.3.0 SUMMARY

Ores are associations of minerals (rocks) in which ore minerals are present in economically significant quantities. Ore minerals are themselves, or contain, valuable elements that can be profitably extracted if the ore mineral(s) is (are) present in sufficient quantity. Ore minerals are fairly common and are widely distributed in the earth's crust where they form by generally well understood geological processes. Ores, on the other hand, represent concentrations of ore minerals 10's, 100's and 1000's of times the average crustal abundances of these minerals and their elements. Ore deposits and the localized districts in which they occur, therefore, represent anomalous crustal conditions. Intelligent prospecting takes into account this anomalous character of ore deposits and utilizes every available means of identifying such areas.